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Marr et al.

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(54) **NETWORK TRAFFIC PRIORITIZATION**

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(73) Assignee: **Sony Computer Entertainment Inc.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

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(51) **Int. Cl.**
G06F 15/16 (2006.01)

(52) **U.S. Cl.** **709/226**; 709/228; 709/229; 713/154; 370/252

(58) **Field of Classification Search** 709/220, 709/226, 229; 370/231, 352; 713/154
See application file for complete search history.

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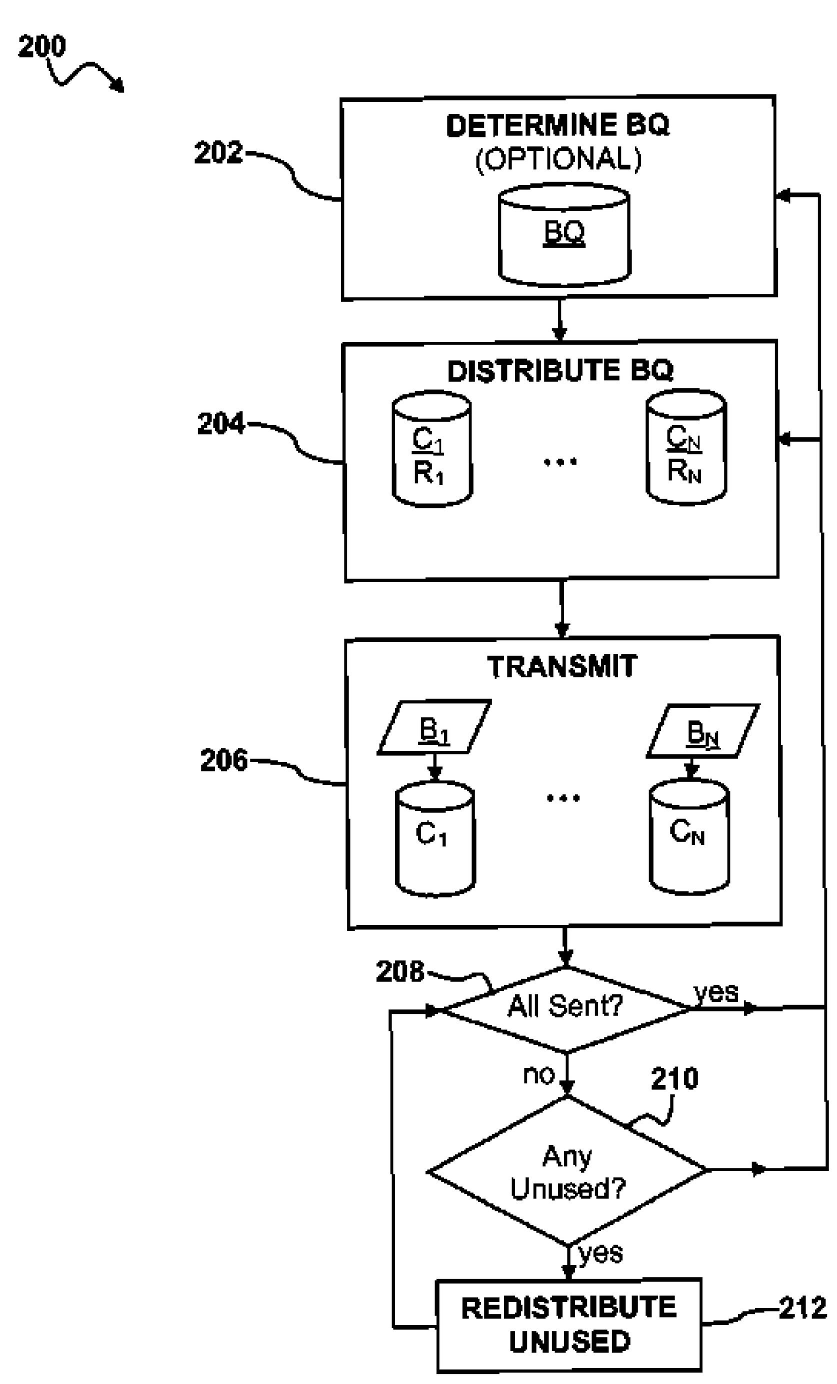
Primary Examiner — Khanh Q Dinh
(74) *Attorney, Agent, or Firm* — Joshua D. Isenberg; JDI Patent

(57) **ABSTRACT**

Prioritizing network traffic among two or more distinct channels of communication within a single application in a node configured to communicate with one or more other nodes over a network is disclosed. For a particular time quantum, a bandwidth quantum may be distributed amongst two or more communication channels according to priorities associated with those channels.

31 Claims, 4 Drawing Sheets



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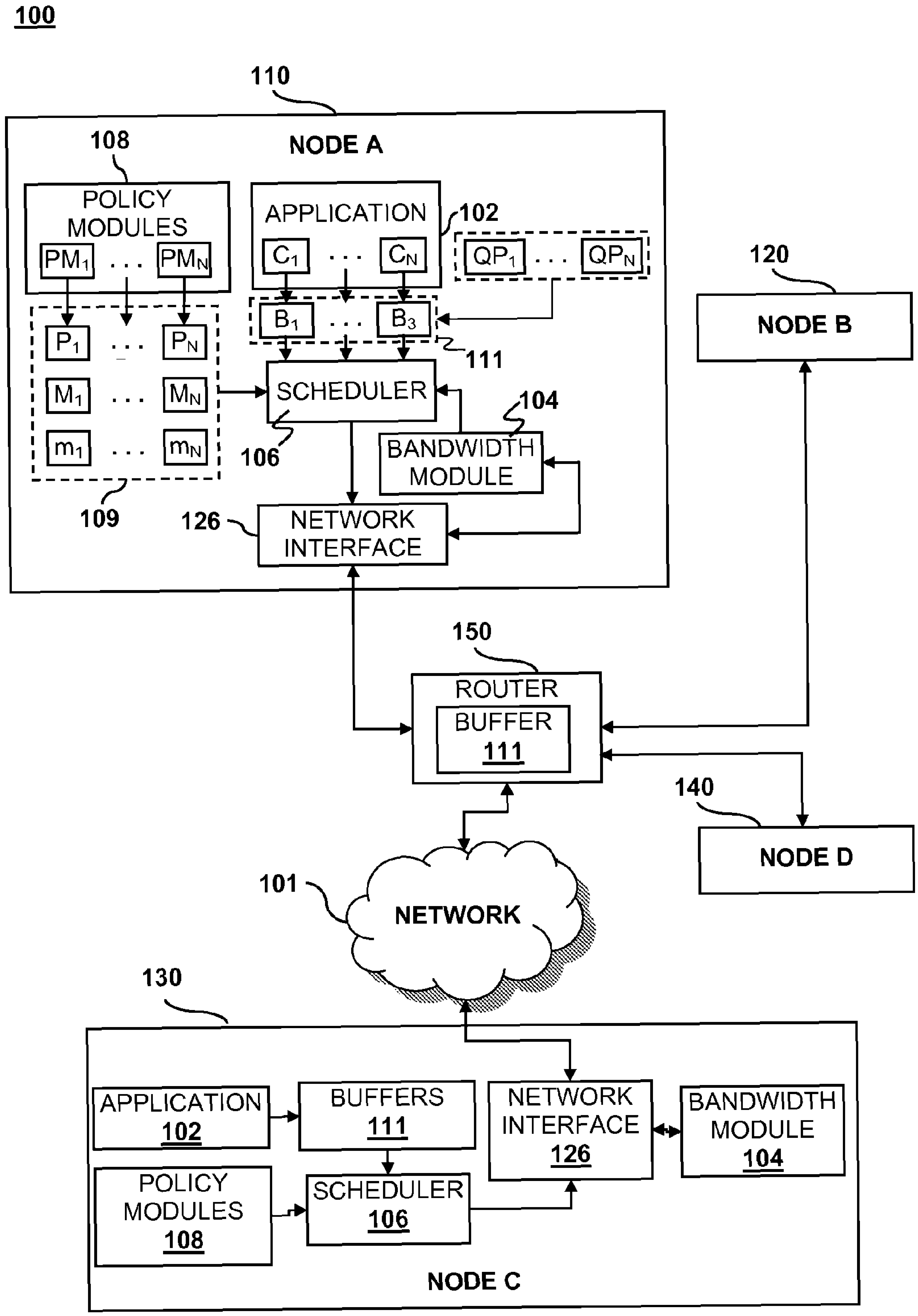
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M1 . . . MN
m1 . . . mN
B1 . . . B3
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104
BANDWIDTH MODULE
106
109
126
NETWORK INTERFACE
120
NODE B
150
ROUTER
BUFFER
111
140
NODE D
101
NETWORK
130
APPLICATION
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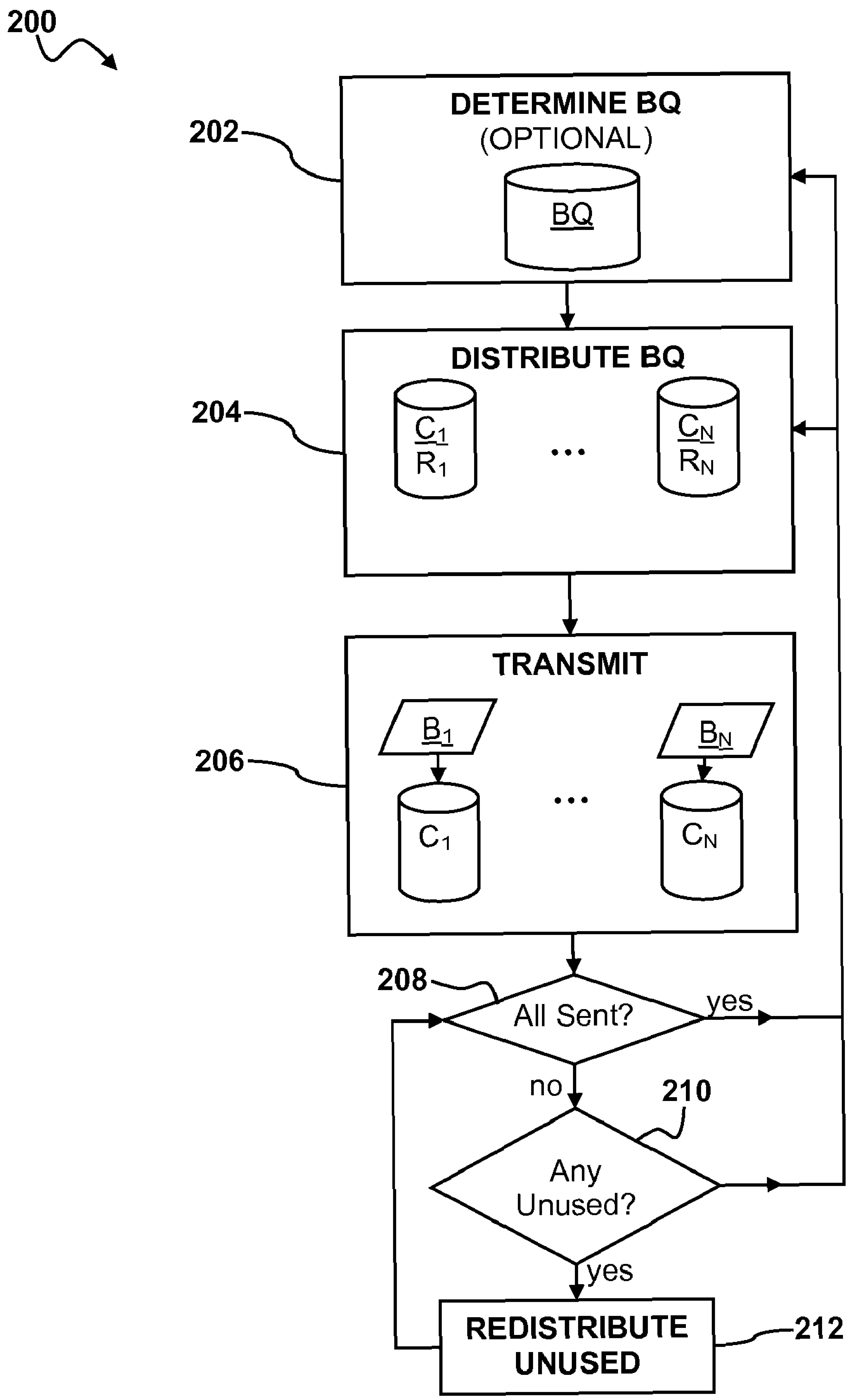
NODE C

FIG. 1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Any
Unused?
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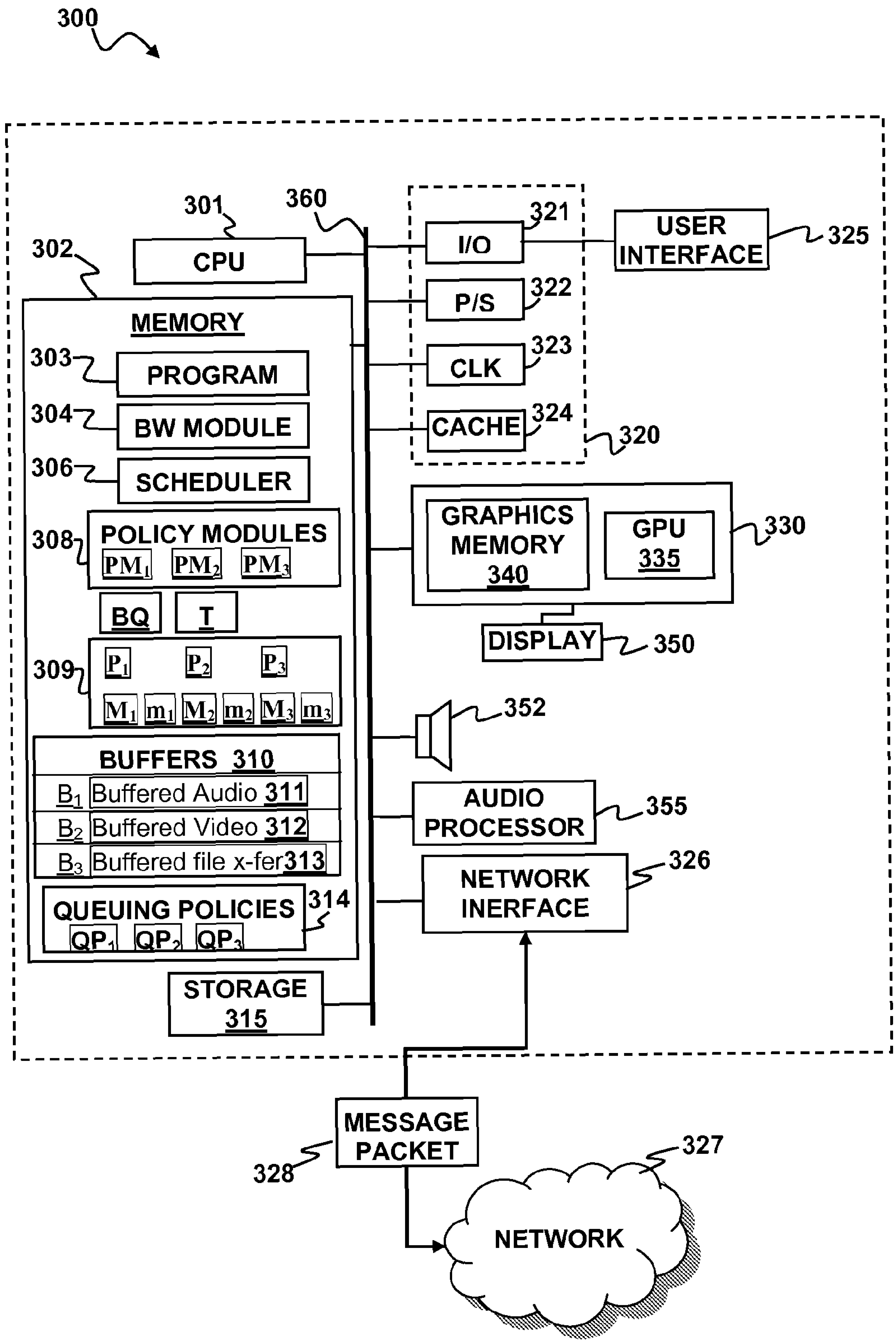
REDISTRIBUTE
UNUSED
212

FIG. 2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P1 P2 P3
M1 m1 M2 m2 M3 m3
BUFFERS 310
B1 Buffered Audio 311
B2 Buffered Video 312
B3 Buffered file x-fer313
QUEUING POLICIES
314
QP1 QP2 QP3
STORAGE 315
I/O
321
P/S
322
CLK
323
CACHE
324
320
USER INTERFACE
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GRAPHICS MEMORY 340
GPU 335
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AUDIO PROCESSOR
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NETWORK INERFACE
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MESSAGE PACKET
328
NETWORK
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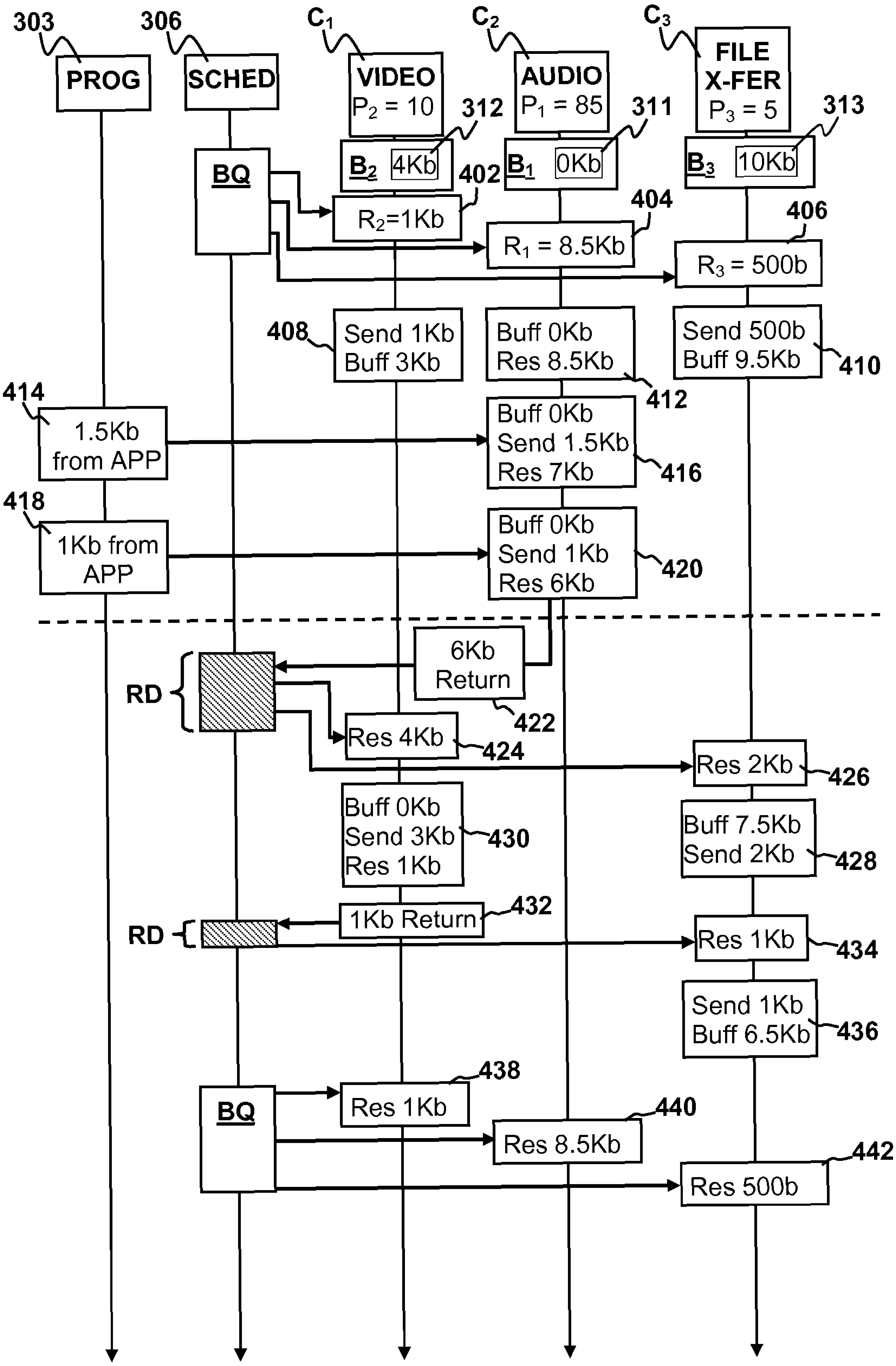
FIG. 3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313
BQ
B2 4Kb
B1 0Kb
B3 10Kb
402
R2=1Kb
404
R1 = 8.5Kb
406
R3 = 500b
408
Send 1Kb
Buff 3Kb
Buff 0Kb
Res 8.5Kb
412
Send 500b
Buff 9.5Kb
410
414
1.5Kb
from APP
Buff 0Kb
Send 1.5Kb
Res 7Kb
416
418
1Kb from
APP
Buff 0Kb
Send 1Kb
Res 6Kb
420
6Kb
Return
422
RD
Res 4Kb
424
Res 2Kb
426
Buff 0Kb
Send 3Kb
Res 1Kb
430
Buff 7.5Kb
Send 2Kb
428
1Kb Return
432
RD
Res 1Kb
434
Send 1Kb
Buff 6.5Kb
436
BQ
Res 1Kb
438
Res 8.5Kb
440
Res 500b
442

FIG. 4

NETWORK TRAFFIC PRIORITIZATION

CLAIM OF PRIORITY

This application is a continuation of commonly-assigned, U.S. patent application Ser. No. 12/267,233 to James E. Marr, Yutaka Takeda, Attila Vass, Payton White and Stephen C. Detwiler entitled "NETWORK TRAFFIC PRIORITIZATION"filed Nov. 7, 2008 now U.S. Pat. No. 7,856,501, the entire disclosures of which are incorporated herein by reference.

This application claims the priority benefit of commonly-assigned, co-pending U.S. Provisional Patent application No. 60/992,295 to James E. Marr, Yutaka Takeda, Attila Vass, Payton White and Stephen C. Detwiler entitled "NETWORK TRAFFIC PRIORITIZATION" filed Dec. 4, 2007, the entire disclosures of which are incorporated herein by reference.

This application claims the priority benefit of commonly-assigned, U.S. Provisional Patent application No. 60/992,282 to Yutaka Takeda, James E. Marr, Stephen C. Detwiler, Attila Vass, and Payton White entitled "NETWORK BANDWIDTH DETECTION AND DISTRIBUTION", filed Dec. 4, 2007, the entire disclosures of which are incorporated herein by reference.

This application claims the priority benefit of co-pending U.S. patent application Ser. No. 12/267,269 to James E. Marr, Yutaka Takeda, Attila Vass, Payton White and Stephen C. Detwiler entitled "NETWORK BANDWIDTH DETECTION, DISTRIBUTION AND TRAFFIC PRIORITIZATION" filed Nov. 7, 2008, the entire disclosures of which are incorporated herein by reference.

This application claims the priority benefit of co-pending U.S. patent application Ser. No. 12/267,254 to Yutaka Takeda, James E. Marr, Stephen C. Detwiler, Attila Vass, and Payton White entitled "NETWORK BANDWIDTH DETECTION AND DISTRIBUTION" filed Nov. 7, 2008, the entire disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to computer network communication, and more specifically to prioritizing network traffic among distinct channels of communication within a single application.

BACKGROUND OF THE INVENTION

Computing systems are becoming increasing interconnected through network environments. Such network environments may be centralized or decentralized. A decentralized computing environment may be defined by a number of computing systems interconnected to communicate with one another, wherein each computing system can perform both client and server functions. A peer-to-peer (P2P) network represents an example of a decentralized computing environment in which each computing system within the P2P network is defined as a peer of every other computing system within the network. For discussion purposes, each peer computing system within the P2P network is referred to as a node. Additionally, each node within the P2P network may be configured to execute software having substantially equivalent functionality. Therefore, each node may act as both a provider and a user of data and services across the P2P network. Peer to peer networks are distributed data networks without any centralized hierarchy or organization. Peer to peer data networks provide a robust and flexible means of communicating information between large numbers of computers or other information devices, referred to in general as nodes.

A P2P network relies primarily on the computing power and bandwidth of the participants in the network rather than concentrating it in a relatively low number of servers. P2P networks are typically used for connecting nodes via largely ad hoc connections. Such networks are useful for many purposes. P2P networks may be used, e.g., for sharing content files containing audio, video, data or anything in digital format is very common, and real-time data, such as telephony traffic, may also be transmitted using P2P technology.

P2P applications often involve a significant amount of communication between nodes over different communication channels. By way of example, such channels may include an audio channel, a video channel, and a file transfer channel. A given application, e.g., audio-video (A/V) chat may communicate using all three channels. Typically, an application has a limited amount of network bandwidth available for communication. The application distributes the available bandwidth among the communication channels.

Prior art network implementations involving multiple communication channels typically adopt an "all or nothing" approach that can lead to starvation. For example, consider a very low bandwidth situation where a user is attempting to engage in A/V chat involving transmission of captured audio and video frames. If the user does not have enough bandwidth available to transmit all of the captured audio and video frames, prior art techniques typically gives complete priority to the audio frames and not transmit any video frames. This may reduce quality of service for the A/V chat.

It is within this context that embodiments of the present invention arise.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention may be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which

FIG. **1** is a block diagram of networked devices illustrating prioritization of network traffic according to an embodiment of the present invention.

FIG. **2** is a flow diagram illustrating a method of for prioritizing network traffic according to an embodiment of the present invention.

FIG. **3** is a block diagram of a node configured to implement network traffic prioritization according to an embodiment of the present invention.

FIG. **4** is a flow diagram illustrating a particular example of prioritizing network traffic amongst audio, video and file transfer channels in a node of the type shown in FIG. **3** according to an embodiment of the present invention.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Although the following detailed description contains many specific details for the purposes of illustration, anyone of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Accordingly, the exemplary embodiments of the invention described below are set forth without any loss of generality to, and without imposing limitations upon, the claimed invention.

According to embodiments of the present invention, bandwidth starvation issues may be avoided by prioritizing network traffic among distinct channels of communication within a single application. FIG. **1** depicts a flow diagram of a method **100** for prioritizing network traffic among two or more distinct channels of communication within a single application in a node configured to communicate with one or more other nodes over a network. Embodiments of the present invention may be understood by referring to FIG. **1** and FIG. **2**.

As seen from FIG. **1**, several nodes, e.g., Node A **110**, Node B **120**, Node C, **130** and Node D **140** may be configured to communicate over a network **101**. Each node may include a network interface **126** to facilitate communication over the network **101**. Two or more nodes, e.g., Node A **110** and Node B **120** may be behind a router **150**. Two or more nodes may run an application **102** that allows the two nodes two communicate over two or more distinct channels $C_1 \ldots C_N$, where N is greater than or equal to 2. Each channel represents a different mode of communication of data traffic. The data for each mode communication may be formatted differently from that of the others. Examples of "channels" include, but are not limited to, audio streams, video streams, file transfer, drawing commands on a shared whiteboard, or any other bulk classification of data traffic. By way of example, and without loss of generality, the application **102** may be an audio-video (A/V) chat application involving audio, video and file transfer channels.

Each node **110**, **120**, **130**, **140** may include a bandwidth module **104**, which may be implemented in software or hardware. The bandwidth module **104** is responsible for estimating the available bandwidth for communication with the other nodes. For example, if Node A **110** is participating in audio video chat with Node C **130** and Node D **140**, the bandwidth module estimates the available bandwidth Node A **110** has for communication with Node C **130** and Node D **140**. Similarly, the bandwidth module **104** at Node C **130** may estimate the available bandwidth node C **130** has for communication with Node A **110** and Node D **140**. In embodiments of the present invention, it is desirable to have accurate bandwidth estimates. A specific example of a bandwidth detection module is described in commonly assigned U.S. Provisional Patent Application 60/992,282, to Yutaka Takeda et al, entitled NETWORK BANDWIDTH DETECTION AND DISTRIBUTION. Network traffic prioritization may be implemented by a scheduler **106** running on one of the nodes, e.g., Node A **110**. The scheduler **106** may be implemented in software, hardware, or some combination of software and hardware. By way of example, and without loss of generality, the scheduler **106** may be programmed with instructions that implement a method **200** for prioritizing network traffic illustrated in FIG. **2**.

As seen from FIG. **2**, at **202** a bandwidth quantum BQ may be determined for a given time interval referred to herein as a time quantum T. Although the choice of time quantum T is somewhat arbitrary, certain considerations are worth bearing in mind when choosing the size of the time quantum T. For example, a smaller time quantum will be more sensitive to isolated bandwidth changes. A longer time quantum will smooth sudden changes, but will result in the system taking longer to adjust to sudden, large changes. The bandwidth quantum BQ is a total amount of data (e.g., in kilobits (Kb)) that may be transmitted during the time quantum T. The bandwidth quantum BQ may be determined from a known or estimated bandwidth available for communication with a given node, e.g., as obtained from the bandwidth module **104**. The bandwidth quantum BQ may be determined from an estimated bandwidth, e.g., in kilobits per second (Kbps) and the duration of the time quantum T. By way of example, the bandwidth quantum BQ may be determined from a product of a bandwidth estimate and the duration of the time quantum T. As a specific numerical example, suppose that the duration of the time quantum T is 50 milliseconds and the bandwidth module **104** in Node A **110** determines that 500 Kbps of bandwidth are available for communication between Node A **110** and Node C **130** and that 200 Kbps of bandwidth are available for communication between Node A **110** and Node D **140**. The bandwidth quantum BQ for communication between Node A **110** and Node C **130** may be approximately (500 Kbps)(50 ms)=25 kilobits (Kb). Similarly, the bandwidth quantum BQ for communication between Node A **110** and Node D **140** may be approximately (200 Kbps)(50 ms)=10 kilobits (Kb).

The scheduler **106** may be configured to implement the distribution of the bandwidth quantum BQ amongst the available channels $C_1 \ldots C_N$. Referring again to FIG. **2**, at **204** the bandwidth quantum BQ is distributed amongst the communication channels based on priorities $P_1 \ldots P_N$ correspondingly assigned to the channels The channels are assigned corresponding reserved portions of the bandwidth quantum BQ. The size R_i of the reserved portion assigned to a given channel C_i of the N channels is greater than zero. The size R_i may be determined based on the corresponding priority P_i assigned to the given channel C_i. For example, the size R_i of a given reserved portion may be determined by:

$$R_i = BQ \cdot \frac{P_i}{\sum_j P_j},$$

$$\text{where } \sum_j P_j$$

is a sum of the priorities $P_1 \ldots P_N$ for all of the channels $C_1 \ldots C_N$.

The quantity

$$\frac{P_i}{\sum_j P_j}$$

is sometimes referred to herein as the relative priority P_{rel}^i for channel C_i. The scheduler **106** may distribute the bandwidth quantum BQ according to priorities assigned by one or more policy modules **108**. By way of example, the policy modules **108** may include individual policy modules $PM_1 \ldots PM_N$ for each of the communication channels $C_1 \ldots C_N$. The policy modules **108** may generate policy parameters **109** that the scheduler **106** uses to determine the distribution of the bandwidth quantum BQ amongst the channels $C_1 \ldots C_5$. The parameters **109** may include priorities $P_1 \ldots P_N$. The policy modules **108** may assign priorities $P_1 \ldots P_N$ based on the needs of the application **102**. The priorities $P_1 \ldots P_N$ determine how the bandwidth quantum BQ is shared between the communication channels $C_1 \ldots C_N$. Such "bandwidth distribution" may be implemented at some fixed frequency (e.g., 50 Hz in some implementations) by the scheduler **106**. At regular intervals, the scheduler **106** may obtain a bandwidth estimation from the bandwidth module **104**, determine the bandwidth quantum BQ and divide the bandwidth quantum BQ between the communication channels $C_1 \ldots C_N$ based on their priorities $P_1 \ldots P_N$.

As a numerical example, assume the bandwidth module **104** estimates a bandwidth BW of 200 kbps for a certain connection. Further suppose that a software designer has configured the scheduler **106** to assign a priority P_1=100 to an audio channel C_1, a priority P_2=20 to a video channel C_2 and a priority P_3=5 to a file transfer channel C_3. If scheduler **106** is configured to trigger at 50 Hz, the time quantum T is approximately 20 milliseconds. By multiplying the estimated bandwidth BW by the time quantum T one obtains a bandwidth quantum BQ=200 Kbps×0.02 s=4 kb. From the priorities P_1, P_2 and P_2 of 100, 20 and 5 one may calculate relative priorities of P_{rel}^1=100/125=0.8, P_{rel}^2=20/125=0.16 and P_{rel}^3=10/125=0.04. Thus, for this distribution cycle, audio is assigned a portion Rt=3.2 Kb, video is assigned a portion R_2=0.64 Kb and file transfer is assigned a portion R_3=0.16 Kb.

The priorities $P_1 \ldots P_N$ may be assigned to the communication channels $C_1 \ldots C_N$ based on the nature and type of data being transmitted over the channels. For example, in the context of A/V chat, nature of streaming audio data may dictate that an audio channel be assigned a relatively high priority than streaming video data. Specifically, streaming audio tends to be relatively tolerant to packet loss. Streaming audio also tends to use a relatively constant amount of bandwidth (e.g., about 12 Kbps) compared to either video or file transfer.

Streaming video data tends to use a relatively wide range of bandwidth, e.g., about 100-300 Kbps depending on compression, and is tolerant to packet loss. Streaming video tends to be less constant than audio. As a result, a streaming video channel may be assigned a lower priority than a streaming audio channel. File transfer data tends to be unpredictable and intermittent and uses as much bandwidth as is available. Unlike audio and video channels, a file transfer channel could theoretically use an infinite amount of bandwidth if it were available. File transfer data is intolerant to packet loss. File transfer data may be significantly less time insensitive than either video or audio data. Consequently, file transfer data channels may be assigned a significantly lower priority than streaming video channels.

Furthermore, priorities may be assigned based on other considerations, e.g., economic considerations. For example, the data channels $C_1 \ldots C_N$ may include one or more channels devoted to advertising data. The priorities assigned to such advertising channels may be based partly on rates that advertisers are willing to pay to have their advertisements distributed by the nodes. Specifically, within the scheduler **106**, selected ones of the priority modules $PM_1 \ldots PM_N$ associated with advertising channels may be configured to assign a higher priority if a higher advertising rate has been paid.

In addition to priorities, each policy module $PM_1 \ldots PM_N$ may determine maximum values $M_1 \ldots M_N$ and minimum values $m_1 \ldots m_N$ for the portions of the bandwidth quantum BQ that are corresponding assigned to channels $C_1 \ldots C_N$. Such maximum and minimum values may be regarded as a subset of the policy parameters **109**. Generally, for a given channel C_i, $m_1 < M_N$ Maximum and minimum values may be used to tailor the distribution of the bandwidth quantum BQ at **204** to the needs of the application. The maximum and minimum values may have any suitable value. A given minimum value may be as low as zero. A given maximum may be infinite. In some cases, the scheduler **106** may initially assign a give channel C_i a portion that has a size R_i greater than its corresponding maximum value M_i. In such a case, the scheduler **106** may be configured, e.g., by suitable programming, to distribute the difference between R_i and M_i amongst the remaining channels. For example, if a channel C_1 has a maximum bandwidth portion M_1 of 5 Kb and its portion R_1 is 8.5 Kb. The difference, 8.5 Kb−5 Kb=3.5 Kb, may be distributed amongst the remaining channels, e.g., on a pro-rata basis dependent on relative priority. For example, suppose there are only two other channels C_2 and C_3 with relative priorities $P_2^{rel}=0.4$ and $P_3^{rel}=0.1$. The distributor **106** may split up the remaining 3.5 Kb as follows. Channel C_2 could be allocated an amount equal to

$$3.5\text{ Kb}\cdot\frac{0.4}{0.4+0.1}=2.8\text{ Kb}$$

in addition to its regular portion R_2 of the bandwidth quantum BQ. Similarly, channel C_3 could be allocated

$$3.5\text{ Kb}\cdot\frac{0.1}{0.4+0.1}=0.7\text{ Kb}$$

in addition to its regular portion R_3 of the bandwidth quantum BQ.

If a given communication channel C_i has a minimum bandwidth quantum portion m_i all channels of a lower priority that C_i may be excluded from bandwidth distribution at **204** during the time quantum T until a minimum amount of data m_i has been transmitted by the channel C_i. If more than one channel has a minimum, the bandwidth quantum is initially distributed to the highest priority channel with a minimum and any other channels having a higher priority. It is important to select the minimum values $m_1 \ldots m_N$ carefully in order to avoid bandwidth starvation. The minimum amount of data m_i represents a minimum amount of data to be sent by the channel C_i during the time quantum T. The minimum value may also be thought of as an expected minimum size of data to send. It is possible that the provided minimum value may be a best guess, and more or less data could actually be available to send. For example, a channel for audio data may always use close to 12 Kbps, so 12 Kbps may be set as the minimum value m_i for that channel. However, depending on the compression used, the actual amount of data may be slightly below 12 kbps at times or slightly over 12 kbps.

Furthermore the policy modules $PM_1 \ldots PM_N$ may generate parameters associated with queuing policies $QP_1 \ldots QP_N$ to the channels $C_1 \ldots C_N$. Each queuing policy determines what happens when multiple sends (e.g., data units such as packets or frames) are made on a single channel, but cannot all be sent immediately. A given queuing policy QP_i may be matched by a software designer to the type of data being sent through the corresponding channel C_i. The nature of the queuing policy QP_i may depend on the nature of the data being sent over the channel C_i. For example, real time streaming data, e.g., streaming audio or video, may have different requirements than non-streaming data. In the case of video channel C_2, two or more video frames may be captured from a camera at different times. Due to the real-time nature of streaming video data, an older frame may be useless and could be discarded in favor of a newer frame. Thus the video channel C_2 may use a queuing policy that selectively discards older images in favor of the newer images. A similar policy may be implemented for the audio channel C_1. For the file transfer channel C_3, by contrast, it may be more desirable to transmit every packet regardless of age. Consequently, the filer transfer channel C_3 may have a different queuing policy attached it. By way of example, the file transfer channel may have a queuing policy that buffers all packets that cannot be sent during the time quantum T.

Each channel C_i may utilize the bandwidth portion R_i that was assigned to it during the time quantum T. Referring again to FIG. **2**, at **206** ready data may be transmitted for each channel C_i that has any ready data to transmit. The amount of ready data transmitted at **206** for a given channel C_i is generally greater than zero and less than or equal to the size R_i of the reserved portion for the channel C_1. As used herein the term "ready data" refers to data that is available for transmission. Ready data may be available for transmission by virtue of being generated by the application. In some cases, such ready data may be transmitted during the time quantum T as soon as it is generated. In addition, ready data may be available by virtue of being stored in one or more buffers **111**. Generally, the buffers **111** may include N communication channel buffers $B_1 \ldots B_N$ correspondingly associated with communication channels $C_1 \ldots C_N$. In some embodiments, the router **150** may include buffers **111**. As used herein, the term buffer generally refers to a region of computer memory used to temporarily hold data while it is being moved from one place to another. Buffers are used, e.g., when there is a difference between the rate at which data is received and the rate at which it can be processed, or in the case that these rates are variable. Typically, the data is stored in a buffer as it is retrieved from a source of the data (e.g., an input device or program generating the data) or just before it is sent to an output device (e.g., a network interface). In addition, a buffer may be used when moving data between processes within a computer. By way of example, each communication channel buffer may be implemented in hardware, software or some combination of both hardware and software. By way of example, and without limitation, the communication buffers $B_1 \ldots B_N$, may be implemented in software.

If a given channel C_i does not use its entire reserved portion R_i during the time quantum T, any unused part of the reserved portion R_i may be redistributed to the other channels. By way of example, if not all of the ready data has been sent at **208** the scheduler **106** may determine at **210** whether there is any unused reserved portion R_i to redistribute. If there is both unsent data and one or more unused reserved portions of the bandwidth quantum, then at **212** any unused part of any reserved portion R_i may be redistributed amongst any of the N communication channels $C_i \ldots C_N$ having un-transmitted ready data. Such redistribution may take place on a pro-rata basis based on relative priority. This sequence may repeat until all ready data has been sent or there is no unused portion of the bandwidth quantum BQ. Otherwise, the cycle may begin again, e.g., at normal distribution at **204** or (optionally) determination of a new bandwidth quantum BQ at **202**. The cycle may then return repeat continually.

It is noted that the beginning and end of the cycle are somewhat arbitrary. For example, although from FIG. **2** it would appear that redistribution **212** takes place at the end of the time quantum T, redistribution may alternatively take place at the beginning of the time quantum T. Generally, redistribution may take place at some time after normal distribution and transmission in one time quantum and before normal distribution in the next time quantum.

FIG. **3** is a block diagram illustrating the components of a node **300** suitable for implementing network traffic prioritization according to an embodiment of the present invention. By way of example, and without loss of generality, the node **300** may be implemented as a computer system, such as a personal computer, video game console, personal digital assistant, or other digital device, suitable for practicing an embodiment of the invention. The node **300** may include a central processing unit (CPU) **301** configured to run software applications and optionally an operating system. The CPU **301** may include one or more processing cores. By way of example and without limitation, the CPU **301** may be a parallel processor module, such as a Cell Processor. An example of a Cell Processor architecture is described in detail, e.g., in *Cell Broadband Engine Architecture*, copyright International Business Machines Corporation, Sony Computer Entertainment Incorporated, Toshiba Corporation Aug. 8, 2005 a copy of which may be downloaded at http://cell.scei.co.jp/, the entire contents of which are incorporated herein by reference.

In the node **300** a memory **302** may be coupled to the CPU **301**. The memory **302** may store applications and data for use by the CPU **301**. The memory **302** may be in the form of an integrated circuit, e.g., RAM, DRAM, ROM, and the like). A computer program **303** may be stored in the memory **302** in the form of instructions that can be executed on the processor **301**. The instructions of the program **303** may be configured to implement, amongst other things, one or more applications, such as the application **102** described above with respect to FIG. **1**. By way of example, and without loss of generality, the program **303** may include an application, such as an A/V chat application involving two or more channels of communication. Such channels may include, but are not limited to an audio channel C_1, a video channel C_2 and a file transfer channel C_3. The memory **302** may also contain instructions, that, when executed by the CPU **301** implement a bandwidth module **304** having features in common with the bandwidth module **104** described above. The memory **302** may also contain instructions configured to implement a scheduler **306** having features in common with the scheduler **106** described above. The memory **302** may also contain instructions configured to implement one or more policy modules **308** having features in common with the policy modules **108** described above. By way of example and without loss of generality, the policy modules **308** may include an audio policy module PM_1 for the audio channel C_1, a video policy module PM_2 for the video channel C_2, and a file transfer policy PM_3 for the file transfer channel C_3.

The memory **302** may contain data that is generated by or usable by the program **303**, bandwidth module **304**, scheduler **306**, and policy modules **308**. Specifically, such data may include, but is not limited to policy module parameters **309**, a bandwidth quantum BQ and a time quantum T. The policy module parameters **309** may include priorities P_1, P_2, and P_3 respectively associated with the audio channel C_1, video channel C_2, and file transfer channel C_3. The policy module parameters **309** may further include minimum values m_1, m_2 and m_3 respectively associated with the audio channel C_i, video channel C_2 and file transfer channel C_3 as well as maximum values M_i, M_2 and M_3 respectively associated with the audio channel C_1, video channel C_2 and file transfer channel C_3.

In addition, the memory **302** may be configured to include one or more buffers **310** for data generated by the program **303** for transmission via the communication channels. By way of example and without loss of generality, the buffers **310** may include an audio buffer B1 configured to buffer audio channel data **311**, a video buffer B_2 configured to buffer video channel data **312** and a file transfer buffer B_3 configured to buffer file transfer channel data **313**. The scheduler **306** may be configured, e.g., by appropriate programming, to implement buffering of data in accordance with one or more queuing policies **314**. By way of example, and without loss of generality, the queuing policies **314** may include an audio data queuing policy QP_1, a video data queuing policy QP_2 and a file transfer queuing policy QP_3. The queuing policies **314** may be configured, to determine what happens when multiple sends are made on a single channel, but cannot all be sent immediately, e.g., as described above.

The node **300** may further include a storage device **315** that provides non-volatile storage for applications and data. By way of example, the storage device **315** may be a fixed disk drive, removable disk drive, flash memory device, tape drive, CD-ROM, DVD-ROM, Blu-ray, HD-DVD, UMD, or other optical storage devices. The node **300** may also include well-known support functions **320** commonly used in computing systems. Such support functions may include such features as input/output (I/O) elements **321**, power supplies (P/S) **322**, a clock (CLK) **323** and cache **324**.

One or more user input devices **325** may be used to communicate user inputs from one or more users to the node **300**. By way of example, one or more of the user input devices **325** may be coupled to the node **300** via the I/O elements **321**. Examples of suitable input devices **325** include keyboards, mice, joysticks, touch pads, touch screens, light pens, still or video cameras, and/or microphones. In the particular case of A/V chat, it is desirable for the user interface devices **325** to include both a camera and a microphone. A network interface **326** allows the node **300** to communicate with other computer systems via an electronic communications network **327**. The network interface **326** may include wired or wireless communication over local area networks and wide area networks such as the Internet. The node **300** may send and receive data and/or requests for files via one or more message packets **328** over the network **327**.

The node **300** may further comprise a graphics subsystem **330**, which may include a graphics processing unit (GPU) **335** and graphics memory **340**. The graphics memory **340** may include a display memory (e.g., a frame buffer) used for storing pixel data for each pixel of an output image. The graphics memory **340** may be integrated in the same device as the GPU **335**, connected as a separate device with GPU **335**, and/or implemented within the memory **302**. Pixel data may be provided to the graphics memory **340** directly from the CPU **301**. Alternatively, the CPU **301** may provide the GPU **335** with data and/or instructions defining the desired output images, from which the GPU **335** may generate the pixel data of one or more output images. The data and/or instructions defining the desired output images may be stored in buffers **310** and/or graphics memory **340**. In an embodiment, the GPU **335** may be configured (e.g., by suitable programming or hardware configuration) with 3D rendering capabilities for generating pixel data for output images from instructions and data defining the geometry, lighting, shading, texturing, motion, and/or camera parameters for a scene. The GPU **335** may further include one or more programmable execution units capable of executing shader programs.

The graphics subsystem **330** may periodically output pixel data for an image from graphics memory **340** to be displayed on a display device **350**. The display device **350** may be any device capable of displaying visual information in response to a signal from the computer system **300**, including CRT, LCD, plasma, and OLED displays. The node **300** may provide the display device **350** with an analog or digital signal. By way of example, the display **350** may include a cathode ray tube (CRT) or flat panel screen that displays text, numerals, graphical symbols, or images. In addition, the node **300** may include one or more audio speakers **352** that produce audible or otherwise detectable sounds. To facilitate generation of such sounds, the node **300** may further include an audio processor **355** adapted to generate analog or digital audio output from instructions and/or data provided by the CPU **301**, memory **302**, and/or storage **315**. In the particular case of A/V chat, it is desirable for the node **300** to include a graphical display device **350** and an audio speaker **352**.

The components of the node **300**, including the CPU **301**, memory **302**, support functions **320**, data storage **315**, user input devices **325**, network interface **326**, graphics subsystem **330** speaker **352** and audio processor **355** may be operably connected to each other via one or more data buses **360**. These components may be implemented in hardware, software, firmware or some combination of two or more of these.

By way of example, and without loss of generality, software designers may implement embodiments of the present invention in software applications by creating a plurality of communication channels, and assigning a priority and a queuing policy to each one. Data could then be sent through these configured communication channels and the scheduler **306**, policy modules **308**, and queuing policies **314** may control the actual transmission of the data over the network **327**.

FIG. **4** illustrates an example of operation of the operation of a node of the type shown in FIG. **3**. In the example illustrated in FIG. **4** it is assumed, for the purpose of example, that the audio buffer B_1 contains no buffered audio data **311**, the video buffer B_2 contains 4 Kb of buffered video data **312** and the file transfer buffer B_3 contains 10 Kb of buffered data **313** for file transfer. It is also assumed, for the sake of simplicity, that there is no unreserved bandwidth quantum at the beginning of a time quantum T**1**. In this example, the audio channel C_1 has been assigned a priority value $P_1=85$, the video channel C_2 has been assigned a priority value $P_2=10$ and the file transfer channel C_3 has been assigned a priority value $P_3=5$. It is assumed in FIG. **4**, that the size of the available bandwidth for one or more 20 millisecond time quanta has been determined by the bandwidth module **304** to be 500 Kbps. The scheduler **306** therefore determines that the corresponding bandwidth quantum is 10 Kb. Using the formula described above, the scheduler **306** may calculate relative priorities $P_{rel}^1=0.85$, $P_{rel}^2=0.10$ and $P_{rel}^3=0.05$ for the audio channel C_1, video channel C_2 and file transfer channel C_3, respectively. In accordance with the formula $R_i=(P_{rel}^i)(BQ)$, the scheduler **306** may then reserve portions of the bandwidth quantum BQ of $R_2=1$ Kb for the video channel C_2, $R_1=8.5$ Kb for the audio channel C_1 and $R_3=500$ b for the file transfer channel C_2 as indicated at **402**, **404** and **406** respectively. The scheduler **306** may then cause the node **300** to send 1 Kb of the buffered video data **312** and buffer the remaining 3 Kb as indicated at **408**. Similarly, the scheduler **306** may then cause the node **300** to send 500 b of the buffered file transfer data **313** and buffer the remaining 9.5 Kb as indicated at **410**. If no audio data is available, the scheduler **306** may continue to reserve 8.5 Kb for the audio channel C_3 as indicated at **412**. At some later point during the time quantum T**1** the program **303** may generate 1.5 Kb of audio data for the audio channel C_1 as indicated at **414**. This data may be sent over the audio channel C_1 while reserving the remaining (8.5 Kb−1.5 Kb)=7 Kb as indicated at **416**. At some further point in the time quantum T**1** an additional 1 Kb of audio data may be generated by the program **303** as indicated at **418**. This data may be sent over the audio channel C_1 while reserving (7 Kb−1 Kb)=7 Kb as indicated at **420**.

At some point the time quantum T**1** ends and a new time quantum T**2** begins. In this example, 6 Kb remains from the reserved portions R_1, R_2, R_3 of the bandwidth quantum BQ. This remaining portion may be returned for redistribution at the beginning of the new time quantum T**2** as indicated at **422**. The 6 Kb of returned reserved portion provides a redistribution quantum RD that may be distributed on a pro-rata basis amongst any of the channels C_1, C_2 C_3 having un-transmitted ready data, e.g., buffered data.

In this example, the video channel C_2 has 3 Kb of buffered data and the file transfer channel C_3 has 9.5 Kb of buffered data at the beginning of the new time quantum T**2**. Since the audio channel C_1 has no buffered data at this point, the 6 Kb of unused reserved portion is distributed between the video channel C_2 and the file transfer channel C_3. In this example, the priority P_2 for the video channel C_2 is twice as large as the priority for the file transfer channel C_3. The scheduler **306** may therefore reserve 4 Kb of the redistribution quantum RD for the video channel C_2 as indicated at **424** and 2 Kb of the redistribution quantum RD for the file transfer channel C_3 as indicated at **426**. The scheduler **306** may then cause the node **300** to send 2 Kb of buffered file transfer data **313** as indicated at **428**. The remaining 3 Kb of buffered video data **312** may be sent and the leftover 1 Kb reserved as indicated at **430**. The leftover 1 Kb may be returned to the redistribution quantum RD as indicated at **432**. Since, at this point, only the file transfer channel C_3 has buffered data, the entire 1 Kb of the redistribution quantum RD may be reserved for the file transfer channel C_3 as indicated at **434**. The scheduler **306** may then cause the node **300** to send 1 Kb of buffered file transfer data **313** while buffering the remaining 6.5 Kb as indicated at **436**.

At this point in this example, the entire bandwidth quantum BQ has been used and normal distribution may take place for the new time quantum T**2**. For example, if the sizes of the time quantum and available bandwidth are the same as before, 1 Kb may be reserved for the video channel C_2 at **438**, 8.5 Kb may be reserved for the audio channel C_1 at **440** and 500 b may be reserved for the file transfer channel C_3 at **442**. The reserved portions R_1, R_2, and R_3 may be used during the remainder of the new time quantum T**2** in a manner similar to that described above with respect to the previous time quantum T2. Any unused reserved portions may be redistributed at the beginning of a subsequent time quantum.

Although the discussion of FIG. 4 is directed to an example involving three specific communication channels, those of skill in the art will recognize that the concept illustrated in that example may be applied to two channels or more than three channels in any similarly configured node.

While the above is a complete description of the preferred embodiment of the present invention, it is possible to use various alternatives, modifications, and equivalents. Therefore, the scope of the present invention should be determined not with reference to the above description but should, instead, be determined with reference to the appended claims, along with their full scope of equivalents. Any feature described herein, whether preferred or not, may be combined with any other feature described herein, whether preferred or not. In the claims that follow, the indefinite article "A", or "An" refers to a quantity of one or more of the item following the article, except where expressly stated otherwise. In the claims that follow, the expressions first and second are used to distinguish between different elements and do not imply any particular order or sequence. The appended claims are not to be interpreted as including means-plus-function limitations, unless such a limitation is explicitly recited in a given claim using the phrase "means for."

What is claimed is:

1. In a node configured to communicate with one or more other nodes over a network, a method for prioritizing network traffic among two or more distinct channels of communication within a single application, the method comprising:

a) distributing a bandwidth quantum BQ for a time quantum T amongst $N \geqq 2$ communication channels $C_1 \ldots C_N$, based on priorities $P_1 \ldots P_N$ correspondingly assigned to channels $C_1 \ldots C_N$, wherein each channel is assigned a reserved portion of the bandwidth quantum BQ, wherein a size R_i of the reserved portion assigned to a given channel C_i of the N channels $C_1 \ldots C_N$, is greater than zero and wherein R_i is determined based on the corresponding priority P_i assigned to the given channel C_i; and

b) transmitting an amount of ready data, if any, for each channel C_i that is greater than zero and less than or equal to the size R_i of the reserved portion for that channel.

2. The method of claim 1 wherein the size R_i of a given reserved portion is determined by:

$$R_i = BQ \cdot \frac{P_i}{\sum_j P_j},$$

$$\text{where } \sum_j P_j$$

is a sum of the priorities for all of the two or more channels.

3. The method of claim 1, further comprising determining the bandwidth quantum BQ prior to a).

4. The method of claim 1 wherein the two or more communications channels include an audio channel, a video channel, and a file transfer channel.

5. The method of claim 1, further comprising, if the size R_i assigned to a given channel C_i is greater than a predetermined maximum size M_i for the channel C_i, allocating a difference $R_i - M_i$ to one or more other channels.

6. The method of claim 1, further comprising, if the size R_i for a given channel C_i is less than a predetermined minimum size m_i for the channel C_i excluding from a) any channels with lower priority than C_i until the minimum size m_i has been met.

7. The method of claim 6 wherein if more than one of the channels has a predetermined minimum size, a) includes initially distributing the bandwidth quantum BQ to a highest priority channel with a minimum size and any other channels having a higher priority.

8. The method of claim 1 wherein a) comprises determining each priority P_i according to a predetermined policy module for the corresponding channel C_i.

9. The method of claim 8, wherein a) further comprises assigning a maximum and/or minimum value to the size R_i according to the predetermined policy module.

10. The method of claim 1, wherein a) further comprises assigning a maximum and/or minimum value to the size R_i according to a predetermined policy module for the corresponding channel C_i.

11. The method of claim 1 wherein the single application is an audio-video chat application.

12. The method of claim 1, wherein b) further comprises implementing a queuing policy for one or more of the communication channels $C_1 \ldots C_N$.

13. The method of claim 12 wherein implementing the queuing policy includes buffering one or more data units by a given communication channel C_i that cannot be transmitted during the time quantum T.

14. The method of claim 13 wherein implementing the queuing policy includes discarding an older data unit in favor of a new data unit.

15. The method of claim 14 wherein the older data unit and new data unit comprise audio frames or video frames.

16. The method of claim 1, wherein the distinct channels of communication are used within a single peer-to-peer application.

17. A node configured to communicate with one or more other nodes over a network, the node comprising:

a processor; and

a memory coupled to the processor, the memory having therein a set of instructions executable by the processor, the instructions being configured to implement a method for prioritizing network traffic among two or more distinct channels of communication within a single application, the method comprising:

a) distributing a bandwidth quantum BQ for a time quantum T amongst $N \geqq 2$ communication channels $C_1 \ldots C_N$, based on priorities $P_1 \ldots P_N$ correspondingly assigned to channels $C_1 \ldots C_N$, wherein each channel is assigned a reserved portion of the bandwidth quantum BQ, wherein a size R_i of the reserved portion assigned to a given channel C_i of the N channels $C_1 \ldots C_N$, is greater than zero and wherein R_i is determined based on the corresponding priority P_i assigned to the given channel C_i; and

b) transmitting an amount of ready data, if any, for each channel C_i that is greater than zero and less than or equal to the size R_i of the reserved portion for that channel.

18. The node of claim 17, further comprising one or more instructions in memory configured to implement one or more policy modules configured to determine the priorities $P_1 \ldots P_N$ for the corresponding channels $C_1 \ldots C_N$.

19. The node of claim 18, wherein one or more of the policy modules is configured to assign a maximum and/or minimum size to an amount of data that can be transmitted during the time quantum T on one or more of the channels $C_1 \ldots C_N$.

20. The node of claim 18, wherein one or more of the policy modules is configured to assign a maximum and size M_i to an amount of data that can be transmitted during the time quantum T over a given channel C_i wherein the set of instructions is configured to allocate a difference $R_i - M_i$ from a given channel C_i to one or more other channels if the size R_i assigned to the given channel C_i is greater than the maximum size M_i.

21. The node of claim **18**, wherein one or more of the policy modules is configured to assign a minimum size m_i to an amount of data that can be transmitted during the time quantum T over a given channel C_i, wherein the set of instructions is configured to exclude from a) any channels with lower priority than a channel C_i until an amount of data greater than or equal to the minimum size m_i has been sent over the channel C_i.

22. The node of claim **21**, wherein the set of instructions is configured such that a) includes initially distributing the bandwidth quantum BQ to a highest priority channel with a minimum size and any other channels having a higher priority if more than one of the channels is assigned a minimum size to an amount of data that can be transmitted during the time quantum T.

23. The node of claim **17**, wherein the set of instructions is configured such that b) further comprises implementing a queuing policy for one or more of the communication channels $C_1 \ldots C_N$.

24. The node of claim **23**, wherein the set of instructions is configured such that implementing the queuing policy includes buffering one or more data units by a given communication channel C_i, that cannot be transmitted during the time quantum T.

25. The node of claim **23**, wherein the set of instructions is configured such that implementing the queuing policy includes discarding an older data unit in favor of a newer data unit.

26. The node of claim **25** wherein the older data unit and newer data unit comprise one or more audio frames or video frames.

27. The node of claim **17** wherein the single application is an audio-video chat application.

28. The node of claim **17** wherein the two or more communications channels include an audio channel, a video channel, and a file transfer channel.

29. The node of claim **17**, further comprising a bandwidth module configured to determine the bandwidth quantum BQ.

30. The node of claim **17**, wherein the distinct channels of communication are used within a single peer-to-peer application.

31. A tangible, non-transitory, computer-accessible storage medium comprising program instructions, wherein the program instructions are computer-executable on a node to implement a method for prioritizing network traffic among two or more distinct channels of communication within a single application, the method comprising:

a) distributing a bandwidth quantum BQ for a time quantum T amongst $N \geqq 2$ communication channels $C_1 \ldots C_N$, based on priorities $P_1 \ldots P_N$ correspondingly assigned to channels $C_1 \ldots C_N$, wherein each channel is assigned a reserved portion of the bandwidth quantum BQ, wherein a size R_i of the reserved portion assigned to a given channel C_i of the N channels $C_1 \ldots C_N$, is greater than zero and wherein R_i is determined based on the corresponding priority P_i assigned to the given channel C_i; and

b) transmitting an amount of ready data, if any, for each channel C_i that is greater than zero and less than or equal to the size R_i of the reserved portion for that channel.

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